

R E S E A R C H

The Impact of the Swedish Massage on the Kinesthetic Differentiation in Healthy Individuals

Kamil Mustafa, MSc,^{1*} Mariusz Pawel Furmanek, PhD,¹
Aleksandra Knapik, MSc,² Bogdan Bacik, PhD,¹ Grzegorz Juras, PhD¹

¹Department of Human Motor Behavior, The Academy of Physical Education in Katowice, Katowice, Poland,

²MENOS Art of Massage Academy in Katowice, Katowice, Poland

Background: Swedish massage is one of the common treatments to provide optimal start and readiness of athletes. The ability of kinesthetic differentiation (KD) is crucial in sport performance. This skill allows to adapt demanded muscle forces to optimize the motor tasks, and it is responsible for the precision. In the literature, there is no evidence how Swedish massage influences the kinesthetic differentiation.

Purpose: The objective of the study was to evaluate the impact of Swedish massage on the kinesthetic differentiation and muscle strength of hand grip.

Methods: Thirty participants took part in this investigation (17 women and 13 men). The assessment consisted of KD tests conducted on the dominant (DH) and nondominant hand (NDH) after 15 minutes of hand and forearm Swedish massage. The procedure consisted of 13 trials for each extremity. The first three were done for 100% of the participants' capabilities (F_{max}), the next five trials were done using 50% of maximum force (50% of F_{max}), and in the last five trials, the participants tried to use only 50% of their previous force (1/2 of 50%). Finally, the absolute force production error (FPE) was calculated for 50% (FPE_50%) and 25% (FPE_25%).

Results: The two-way repeated measure analysis of variance ANOVA did not reveal any statistically significant changes in maximal strength grip and KD between pre- and postmassage intervention in both DH and NDH hand. Correlations showed strong relationship between pre- and postmassage for maximum force ($r = 0.92, p = .01$ for DH, and $r = 0.94, p = .01$ for NDH), and only for the FPE_50% ($r = 0.67, p = .01$ for DH, and $r = 0.71, p = .01$ for NDH).

Conclusions: The results obtained indicated that the application of the Swedish massage did not affect the kinesthetic differentiation in this particular young adult group.

KEY WORDS: force sense; force production error; hand grip force

INTRODUCTION

The ability to differentiate force plays an important role not only in daily life activity (e.g., grasping a fragile object), but also in sports, where the appropriate sense of force often determines the accuracy task. When developing strategies to prepare athletes for effort, measures to improve movement control are worth considering. Therefore, the kinesthetic differentiation (KD) also known as force sense (tension or effort) within training and rehabilitation process becomes more and more stressed.

As proprioceptive sensations, the kinesthetic differentiation is defined as the ability of an individual to use different levels of muscular force (perception of muscular force).⁽¹⁾ This skill allows an individual to adapt muscle tension to stabilize the joints, and it is responsible for the economy and precision of motor tasks.^(2,3) The highly developed ability of KD often manifests itself in a technique of movements. Adjusting kinesthetic differentiation takes place in the nervous system, and it is mostly based on the afferent information coming from Golgi tendon organs (GTO) and muscle spindles. Apart from these two receptors, an important role of force differentiation is also played by pressure-sensitive skin receptors (mechanoreceptors in the skin), which effectively complement proprioceptive information.⁽⁴⁾

The perception of the muscular force (kinesthetic differentiation) is commonly assessed by using force production tests.⁽⁵⁾ These tests involve using a reference force, usually determined as a percentage of a maximal voluntary isometric contraction (MVC), and attempting to replicate a percentage of MVC — for instance, 25%, 50% or 75%. The difference between the target force and the force produced is used to quantify the accuracy of KD and is referred to as a force production error (FPE). Force matching is usually conducted without visual feedback and can occur in the same limb or in the contra-lateral limb.⁽⁶⁾ In this investigation, the grip strength by means of electronic hand dynamometer was conducted to evaluate KD, since it is a valid tool of measurement for cognitive function.^(7,8) Jones

and Hunter⁽⁵⁾ indicate that the use of 50% of maximum force as the target force generates a smaller error at the attempts to the model force. Furthermore, healthy individuals can reliably distinguish load changes of 5%–10% in an active lifting movement.⁽⁹⁾

Several factors influencing kinesthetic differentiation have been investigated (e.g., age, cryotherapy, warm-up exercises, muscle fatigue).⁽¹⁰⁾ However to our knowledge, no one investigated how Swedish massage influences kinesthetic differentiation. Among many physiotherapy procedures, Swedish massage is one of the common treatments that is used in order to ensure optimal start readiness of athletes.^(11,12) Swedish massage (in Europe also known as classic massage) applied to the subjects of this study is defined as a mechanical manipulation of body tissues with rhythmical pressure and includes various combinations of stroking, rubbing, kneading, tapotement, and vibration.^(12,13) It is interesting to note that the therapeutic effects of the Swedish massage are overestimated and underestimation equally often. Authors usually unanimously list the beneficial after massage effects, such as: (a) reduction of muscle tone; (b) improvement in the flow of nerve impulses at synapses; (c) improvement in reaction time and neuromuscular coordination;⁽¹⁴⁾ (d) stimulation of nerve conduction; improvement in muscular trophic (provision of nutrients, disposal of metabolic waste products); and (e) three- to five-fold increase in muscle readiness to work and in their ability to contract and relax.^(15,16,17) In light of the above assumptions, the idea of applying massage prior to a physical activity seems fully justified. Literature^(11,16) suggests that such procedure is designed to complement the warm-up and improve the physical properties of selected muscle groups and joints, thus to prepare an athlete for training and competition.

Previous studies on massage have mainly been focused on the assessment of endurance, maximal force, and reaction time skills.^(12,13) Nevertheless, there are not enough reports on the effects of massage on the kinesthetic differentiation. This issue needs further exploration, taking into account the concept of a reflex-nervous activity of the massage and the role of this ability in the structure of motor skills. From the perspective of this paper, the impact of the classical massage on the nervous and muscular systems seems particularly interesting, because these systems determine the ability of kinesthetic differentiation.

Thus, the main objective of the study was to assess the impact of the classical massage on kinesthetic differentiation under static conditions. The hypothesis was formulated that massage significantly positive affects the muscle force perception.

METHODS

The study group consisted of 30 purposely selected healthy students from the Academy of Physical

Education in Katowice. It was a homogeneous sampling in terms of age between 20–25 (17 females, age: 21.9±0.78 years, height: 167.4±6.59 cm, body mass: 59.7±4.51 kg, and BMI: 21.3±1.46 and 13 males, age: 22.5±1.33 years, height: 180.8±4.88 cm, body mass: 80±12.57 kg, and BMI: 24.5±3.15). All subjects were Caucasians. Individuals were excluded from the investigation if they had any neurological or orthopedic disorders, cardiovascular disease, sensory disturbances, as well as any contraindications against massage. The experimental methodology was approved by the Research Ethics Board at the Academy of Physical Education in Katowice and in accordance with the ethical standards of the Helsinki Declaration.⁽¹⁸⁾ All data collection was performed in the Human Motor Behavior Laboratory at the Academy of Physical Education in Katowice. All participants signed an informed consent before investigation.

The kinesthetic differentiation test consisted in the assessment of hand grip force for both dominant and nondominant hand. The participants performed 13 trials for each extremity. The first three trials were done for 100% of the participants' capabilities, which allowed the researchers to assess the participants' maximal isometric voluntary contraction force (F_{max}), then five trials were done trying to use 50% of the maximum force, and in the last five trials, the participants tried to use only 50% of their previous force (1/2 of 50%). The result was the difference of force recorded in relation to the norm (1/2 of the maximum result and 1/2 of 50% of force result). The absolute force production error (FPE) expressed in percentage (accuracy of kinesthetic differentiation) was calculated according to the formula:

$$FPE = (|\text{model} - \text{score}|) / \text{model} \times 100\% \quad (1)$$

Analysis took into account the mean values of forces expressed in kilograms. It was the mean value of isometric force measured for 6 s, the first second of the measurement was rejected in order to eliminate any possible delay. The average of three trials was used in the analysis of the maximum hand grip force (F_{max}). There were 30 s breaks between each of them. The average of five trials was considered in the analysis of kinesthetic differentiation of 50% and 25%. Each trial lasted for 6 s (the first second of the measurement was rejected in order to eliminate any possible delay) and there were 30 s breaks between them. Reference values were calculated in the kinesthetic differentiation test (50% of maximum force and 1/2 of 50% force) and on this basis, the percentage value of the absolute force production error was computed for 50% (FPE_50%) and 25% (FPE_25%).

Instructions for the participants were as follows:

1. For the first three trials — tighten your hand with 100% of your capabilities.

- For the five consecutive trials — tighten your hand with half the value (i.e., 50% of your capabilities).
- For the five consecutive trials — tighten your hand with half the previous value (i.e., 1/2 of 50% force).

The study consisted of two kinesthetic differentiation tests. The first measurement showed the natural kinesthetic differentiation of a participant, while the second one was preceded by a 15-min Swedish massage. The second measurement started within 1 min after the completion of massage. The massaged extremity was examined first, then, the other one. The course of procedure is presented in Figure 1.

During the measurement, the participants were sitting in a chair, with the forearm of the examined limb in a neutral position and the flexion at the elbow joint of approximately 90° (Figure 2). This is the standard position to assess the hand grip force, proposed by the American Society of Hand Therapists (ASHT), supported by the research results of other scientists.^(7,19) During the measurements, the participants were blindfolded and did not receive any feedback on the course of trial or their scores. An electronic hand dynamometer (Baseline Hydraulic Hand Dynamometer; Fabrication Enterprises Inc., Irvington, NY, USA) with Hercules 2000 software, JAMAR Handy (Orthopartner AG, Seon, South Korea) was used for measurement (see Figure 3).

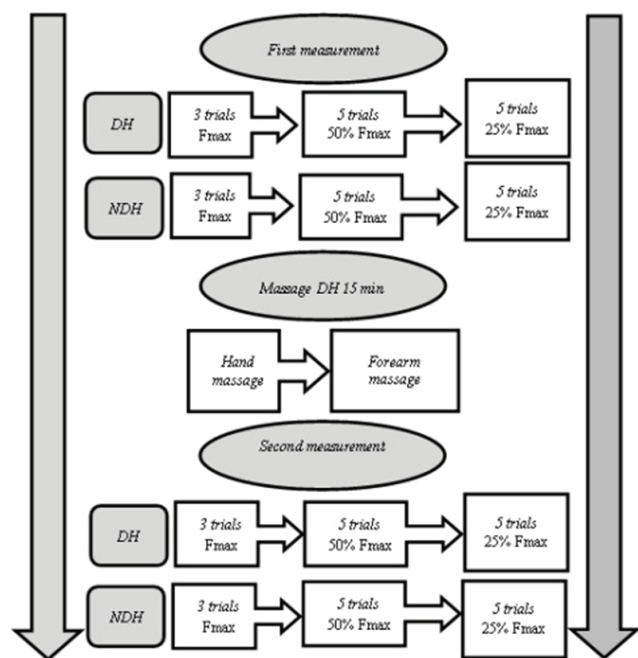


FIGURE 1. Testing procedure. DH = dominant hand, NDH = nondominant hand, F_{max} = maximal force.



FIGURE 2. The standard position of subjects during testing procedure.



FIGURE 3. Hand dynamometer used during investigation.

Massage prior to the second measurement was performed on the hand and forearm of the dominant limb. Applied massage strokes were based on the methodology proposed by Podgorski.⁽¹⁴⁾ During the massage, the participants were sitting with the forearm resting on the table in front of them. The massage included the following proportions of different techniques: 10% of stroking (1.5 min), 30% of rubbing (4.5 min), 40% of kneading (6 min), 10% of tapping (1.5 min), 5% of vibration (45 s), 5% of final stroking (45 s) (see Table 1). All the strokes used were oblong, along the muscle fibers. The massage was performed on the dorsal and palmar side of the hand, as well as the front and back side of the forearm. A metronome with a frequency of 1 Hz was used in order to standardize the pace of the massage. Each massage was performed by the same physiotherapist.

Results obtained in the study were analyzed based on the commonly applied methods of statistical analysis, using STATISTICA 10 software package (StatSoft, Inc., Tulsa, OK, USA).⁽²⁰⁾ The basic parameters of descriptive statistics were calculated, such as:

arithmetic mean, standard deviation, skewness, and kurtosis of distributions. Normality of distribution of the variables was checked with the Shapiro-Wilk test. In order to compare the impact of massage on the kinesthetic differentiation for the dominant and non-dominant limbs, two-way analysis of variance 2×2 ANOVA for repeated measures was used (dominant and nondominant limb \times massage before and after). Post-hoc analysis, the Bonferroni test for multiple pairwise comparisons, was applied to determine the level of statistical significance of differences. In order to correlate maximal force tests and kinesthetic differentiation tests, Pearson's correlation coefficient was calculated. The level of significance for all variables was $p < .05$.

RESULTS

The average value of maximum force (F_{\max} DH) for the dominant hand (DH), after the massage, decreased by 0.49 kg. There was no statistical significance after the application of massage $F_{(1,29)} = 5.5, p = .46$.

TABLE 1. Techniques and Strokes Applied During the Classical Massage

<i>Technique/stroke</i>	<i>Time [s]</i>	<i>Technique/stroke</i>	<i>Time [s]</i>
<i>Hand - dorsal side</i>		<i>Hand - palmar side</i>	
stroking the whole hand	10	stroking the whole hand	10
rubbing the fingers with the tips of thumbs	10	rubbing the fingers with the tips of thumbs	10
rubbing the metacarpophalangeal joints with the tips of thumbs	10	rubbing the metacarpophalangeal joints with the tips of thumbs	10
rubbing the interosseous spaces with the tips of thumbs	15	rubbing the metacarpus with the tips of thumbs	15
rubbing the interosseous spaces with the tips of fingers 2-5	10	rubbing the metacarpus with the heel of the hand	10
rubbing the metacarpus with the heel of the hand	15	rubbing the metacarpus in a screw motion	15
final stroking	10	kneading the thenar eminence and hypothenar eminence of the little finger – slide motion	40
		final stroking	15
<i>Forearm - back side</i>		<i>Forearm - front side</i>	
stroking: oblong with one hand, with two hands in turns	30	stroking: oblong with one hand, with two hands in turns	30
rubbing with the tips of fingers 2-5	15	rubbing with the tips of fingers 2-5	15
rubbing with the bent phalanges	15	rubbing with the bent phalanges	15
rubbing with the fist	15	rubbing with the fist	15
rubbing with the heel of the hand	15	rubbing with the heel of the hand	15
mortar rubbing	15	mortar rubbing	15
single kneading	50	single kneading	50
double kneading	50	double kneading	50
extrusion - with one hand, with and without pulsation	60	extrusion - with one hand, with and without pulsation	60
broom tapping	45	broom tapping	45
vibration + shaking: labile	25	vibration + shaking: labile	20
final stroking: oblong with one hand, with two hands in turns	15	final stroking: oblong with one hand, with two hands in turns	15

The average value of maximum force (F_{\max} NDH) for the nondominant hand (NDH), after the massage, decreased by 1.3 kg. There was no statistical significance $F_{(1,29)} = 3.5, p = .71$. The dependencies for the dominant and nondominant hand are shown in Figure 4.

For the dominant hand, after the massage, the percentage value of error in the assessment of 50% of maximum force (FPE_50% DH) increased by 1.63%. There was no statistically significant difference found $F_{(1,29)} = 3.2, p = .57$. The percentage value of error in the assessment of 25% of maximum force (FPE_25% DH) after the massage decreased by 2.2%. There were no statistical significance $F_{(1,29)} = 4.5, p = .51$. These dependencies are illustrated in Figure 5.

In the nondominant hand, after the massage, the percentage value of error in the assessment of 50% of maximum force (FPE_50% NDH) increased by 3.27%. There was no statistical significance $F_{(1,29)} = 1.5, p = .22$. The percentage value of error in the assessment of 25% of maximum force (FPE_25% NDH) after the massage increased by 0.62%. There was no statistical significance $F_{(1,29)} = 0.3, p = .86$. These dependencies are shown in Figure 6.

Correlations of maximal grip strength force (F_{\max}) between pre- and postmassage were significant both for dominant ($r = 0.92, p = .01$), and nondominant

hand ($r = 0.94, p = .01$). These trends are shown on Figures 7 and 8.

For kinesthetic differentiation tests, correlation reveal significant relationship between pre- and post-massage of 50% force production error ($r = 0.67, p = .01$) for DH and ($r = 0.71, p = .01$) for NDH. These correlations are shown on Figures 9 and 10. For the pre- and postmassage of 25% force production error, the correlations were insignificant both for dominant ($r = 0.06, p = .72$), and nondominant hand ($r = 0.22, p = .25$).

DISCUSSION

The present study indicates that the Swedish massage of the hand and the forearm does not affect the kinesthetic differentiation, manifesting itself in the sense of hand grip force. It could be assumed that some differences in this area would be noted as a result of mechanical influence on the chosen analyzers of the nervous system (muscle spindles, Golgi tendon organs, and pressure-sensitive skin receptors). Magiera⁽¹⁵⁾ and Walaszek⁽¹⁶⁾ suggest that, by stimulating different kinds of receptors, a massage induces the stimulation of certain areas of the cerebral cortex, which translates into faster and more efficient implementation of operations by organs. This process is associated with a central (general) impact of the Swedish massage. However, there are not enough reliable scientific reports that could verify this dependency. The influence of the Swedish massage on the kinesthetic receptors has not been examined yet.

Numerous scientific reports have updated the current state of knowledge on the subject and discovered new dependencies, often in opposition to the information contained in the published books. Some studies^(21,22,23,24) suggest that massage, similar to stretching, causes a decrease in the activation of motor units and reduces muscle tone, which can translate into motor efficiency in motor tasks requiring a high level of force. This phenomenon

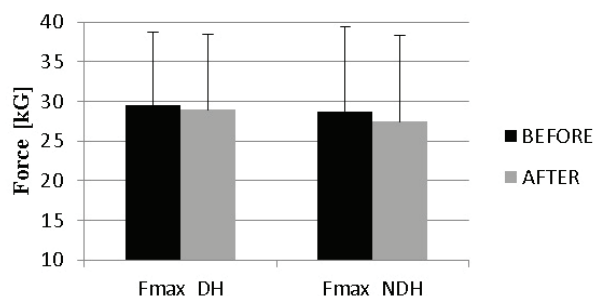


FIGURE 4. Average values of maximal force (F_{\max}) in dominant (DH) and nondominant (NDH) hand before and after massage.

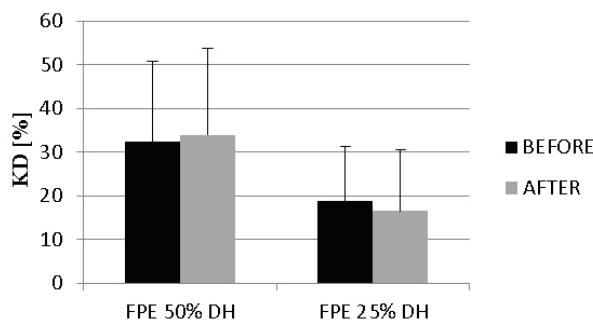


FIGURE 5. Percentage value of force production error (FPE) in dominant hand (DH) estimated for 50% and 25% of maximal force before and after massage. KD = kinesthetic differentiation.

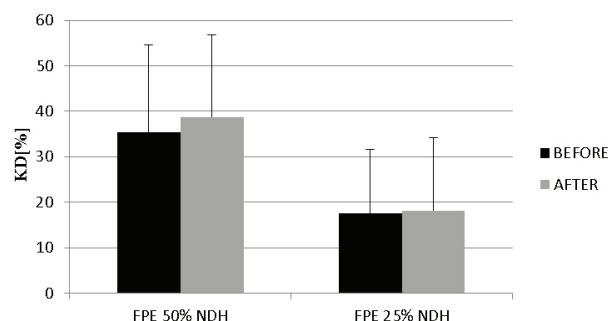


FIGURE 6. Percentage value of force production error (FPE) in nondominant hand (NDH) estimated for 50% and 25% of maximal force before and after massage. KD = kinesthetic differentiation.

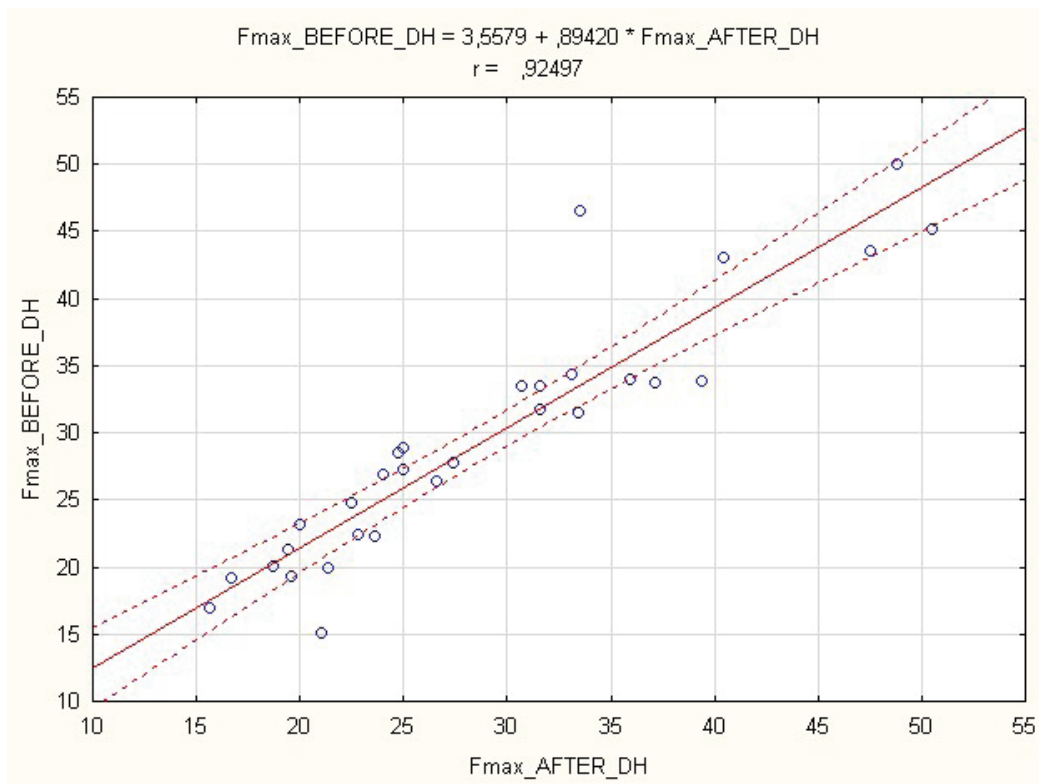


FIGURE 7. Correlation between pre- and postmassage for maximal grip strength (F_{max}) for dominant hand (DH).

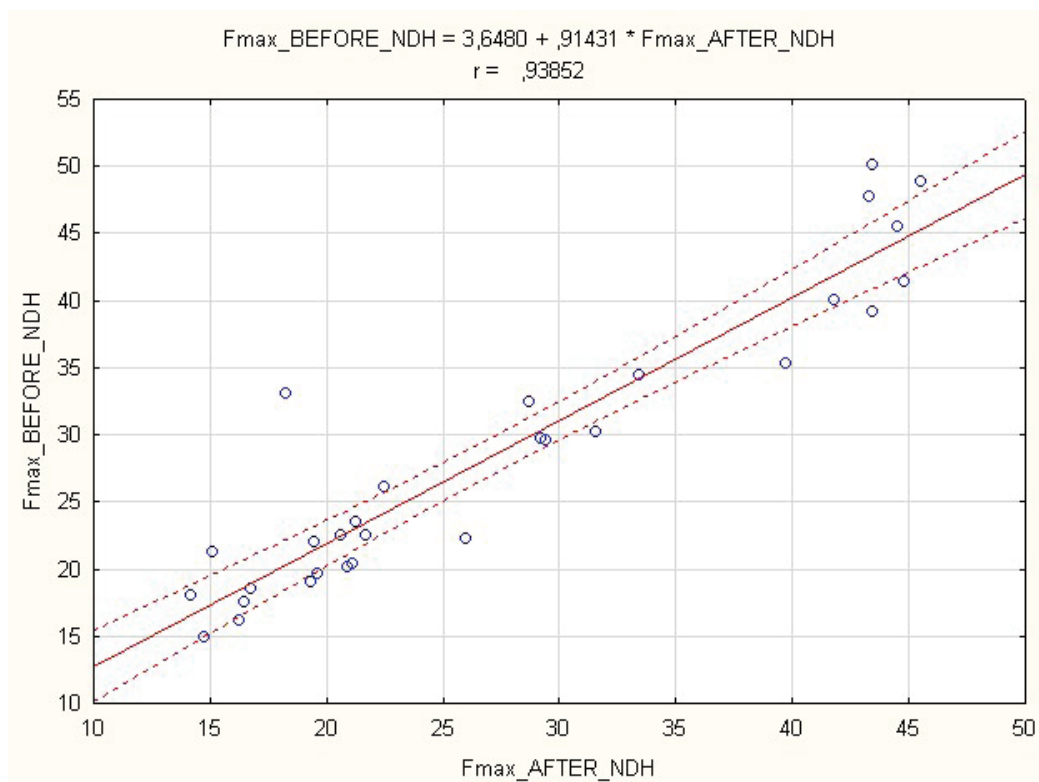


FIGURE 8. Correlation between pre- and postmassage for maximal grip strength (F_{max}) for nondominant hand (NDH).

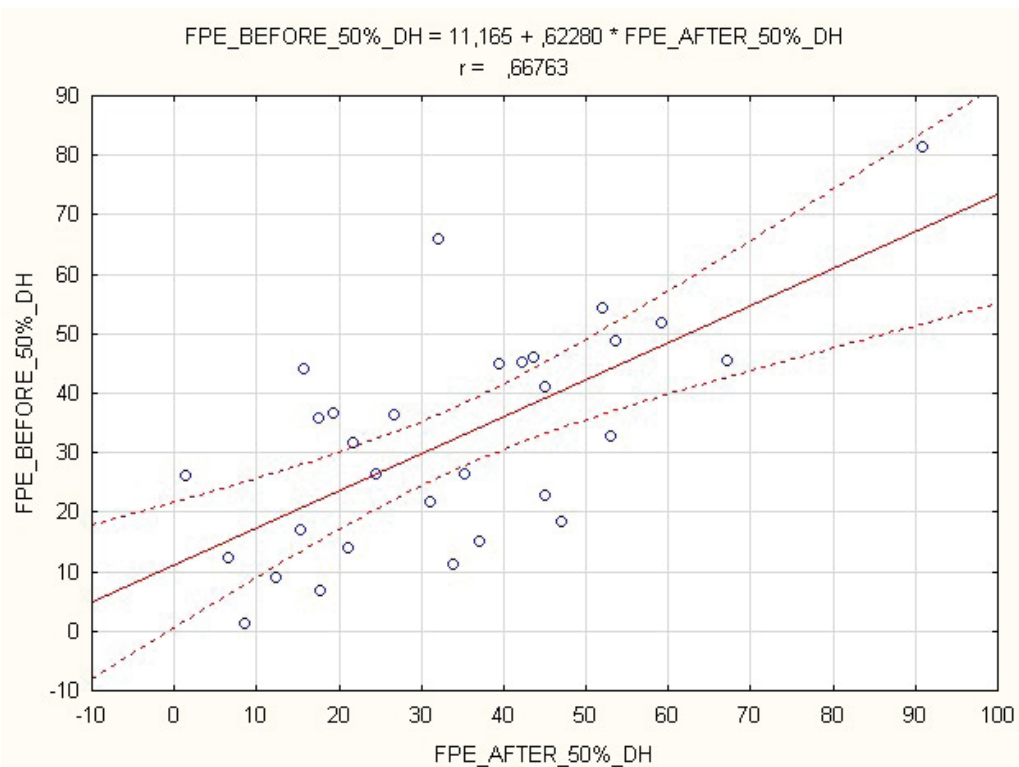


FIGURE 9. Correlation between pre- and postmassage for kinesthetic differentiation expressed as force production error of 50% for dominant hand (DH).

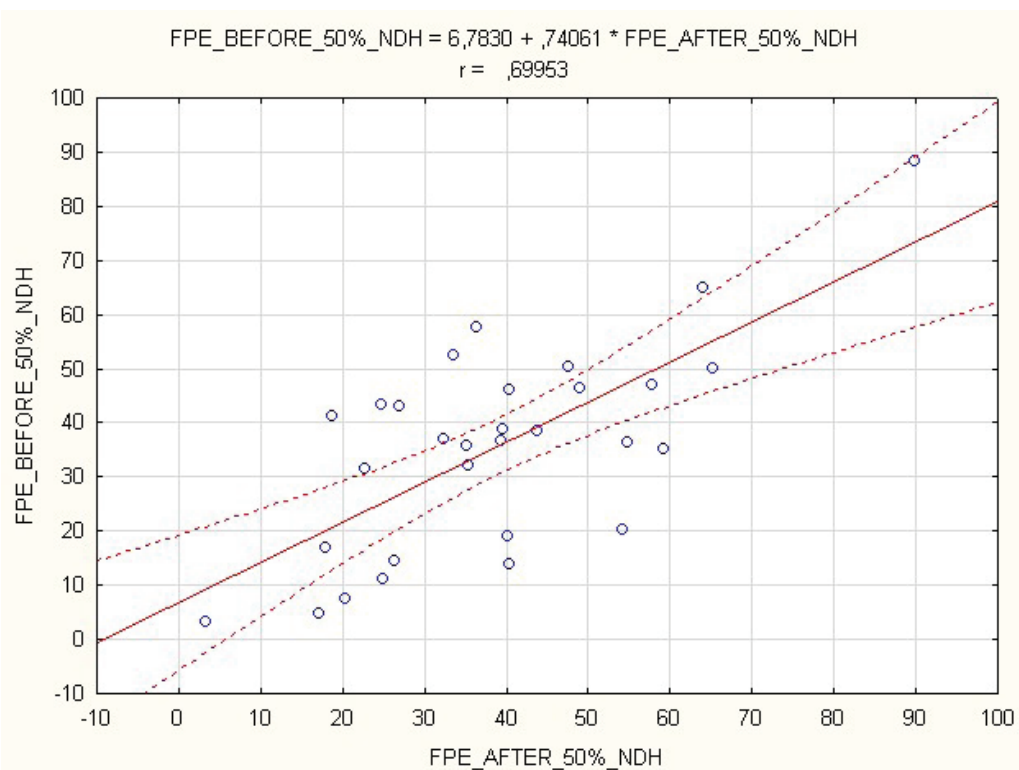


FIGURE 10. Correlation between pre- and postmassage for kinesthetic differentiation expressed as force production error of 50% for nondominant hand (NDH).

is explained by, among other factors, a decrease in the number of potential actin-myosin bridges in elongated muscles.^(25,26) This relationship has been shown in several publications that have demonstrated that massage has a negative impact on the scores in speed and explosive power tests.^(27,28,29) However, some researchers^(30,31) have not noticed any changes in this area after the treatment, compared with the control group. There is no complete agreement with regard to the impact of massage on the sphere of human motor skills. In the face of insufficient evidence and conflicting research results, it is difficult to draw unequivocal conclusions. However, also it is difficult to give an unequivocal assessment, as it is usually subjective and qualitative.

Some researchers^(22,23) observed a sedative impact of a massage on the tension of massaged muscles by reducing neuromuscular excitability, measured with changes in Hoffman reflex amplitudes (so-called H-reflex). Interestingly, the inhibitory effect of massage on alpha motor neurons maintained only during the treatment.⁽²⁴⁾ After its completion, the excitability of motor units quickly returned to their previous levels, which suggests that the change would not be recorded in the results of posttreatment measurements. Therefore, some researchers⁽¹²⁾ believe that the possible differences in the muscle tone after the massage should not be explained by the reduced activity of alpha motor neurons, but the change in the structure of the muscle (fiber elongation, reduction in soft tissue adhesion).^(32,33) Nevertheless, the impact of massage on the neurological aspects of muscle tension needs further examination.

The present study also evaluated the influence of the Swedish massage on the maximum force of isometric contraction during the hand grip test. It has been found that the massage did not affect the mean values of maximum force, which had been concluded also by Hemmings et al.,⁽³⁴⁾ Jönhagen et al.,⁽³⁵⁾ and McKechnie et al.,⁽³⁶⁾ who did not find any influence of massage on the results of force tests. Yet, some authors claim that massage by mechanical pressure exerted on the soft tissues increases their deformability and causes stretching of the shortened muscle fibers, which in turn results in a decrease of the muscles' potential force.⁽¹²⁾ The process is explained by the lower number of possible actin-myosin connections in the elongated muscle.^(25,26) There is also the neurological factor hypothesis, which blames the reduced activation of muscle fibers or a change in their reflex sensitivity for a decrease in force after the massage.⁽²⁸⁾ The postmassage decline of force had been found by Wiktorsson-Moller et al.,⁽³⁷⁾ Hunter et al.,⁽³⁸⁾ and Arroyo-Morales et al.,⁽²¹⁾ among others. However, a comparison of the above results with the findings of the present study is problematic, since the said researchers had taken into account the manifestations of force under dynamic conditions, tested larger muscle groups and used different massage protocols.

The lack of a control group constitutes a limitation of the study. The nondominant hand was the only reference point. It was not assessed whether the pauses between measurements were sufficient to eliminate fatigue, which could have affected the results. Only subjective preferences of the subjects were taken into account when setting the grip span of dynamometer. Since the efficiency of hand grip is determined by the grip span, it is suggested to base the adjustment of dynamometer also on the hand size, which will make the measurements more objective.^(39,40,41) Assuming that, massage contributes to a decline in muscle force, the results of the present study may have been affected by the Hawthorne effect (observer effect). The participants of the experiment could expect that after the massage, their hand grip would be stronger, making them more motivated to achieve higher results, which could have eliminated the negative impact of the treatment. In future studies, subjective feelings of the participants should be taken into account with regard to the impact of massage on the psychological sphere. The results could have also been affected by the therapist's experience and training, since they imply particular pressure force, choice of techniques, and professional skills. Moreover, it is important to note that the message applied aimed neither at sedation, nor stimulation of muscles, but it rather combined existing techniques. In addition, the results of the present experiment should be interpreted only with reference to young and fit individuals, as no other subjects were examined.

Correlations before and after massage intervention revealed that there is strong relationship for maximum grip strength and for kinesthetic differentiation tests as a cognitive functional, only when subjects were asked to differentiate force at the 50% level of maximal grip strength. This correlations were significant both for dominant and nondominant hand. However, the ANOVA did not showed any significant differences after 15-min Swedish massage intervention. The 25% force differentiation test showed that force production error (FPE_25%) demonstrated high individual variability and indicated that this test should be conducted with particular caution in the future.

The results of this investigation suggest that massage does not improve the examined parameters; therefore, it does not constitute a significant component of preparation to a physical activity. On the other hand, massage does not affect the kinesthetic differentiation and it can be safely used before activities which demand high movement precision.

CONCLUSION

The applied Swedish massage does not significantly affect the kinesthetic differentiation and the values of maximum force in this particular studied group.

ACKNOWLEDGMENTS

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CONFLICT OF INTEREST NOTIFICATION

The authors declare there are no conflicts of interest.

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Corresponding author: Kamil Mustafa, Department of Human Motor Behavior, The Jerzy Kukuczka Academy of Physical Education in Katowice, 72A Mikołowska Street, 40-065 Katowice, Poland
E-mail: kamilmustafa@wp.pl